

PATENT SPECIFICATION

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(54) DROP DISPENSING APPARATUS

(71) We, AMERICAN HOSPITAL SUPPLY CORPORATION, a Corporation organised under the laws of the State of Illinois, United States of America of 1740 Ridge Avenue, Evanston, Illinois, United States of America do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

As is well known, a variety of laboratory test procedures involve the dropwise addition of reagents to institute, maintain, or interrupt reactions. A typical test, used in the field of immunohaematology and blood banking, is the Coombs antihuman globulin test in which one drop (in the indirect Coombs test; two drops in the direct test) of antihuman serum, also known as Coombs serum, prepared from the blood of animals which have been immunized against purified human globulin, is added to a sample of red blood cells to be tested for the purpose of promoting visible agglutination of those erythrocytes which have become coated or sensitized by prior immunologic reaction. If agglutination occurs, it demonstrates the occurrence of a previous reaction between the blood cell antigens and antibody. The tests may be used in preparing blood for use in transfusion, with donor's cells and recipient's serum being mixed to ascertain if a combination of antigen and antibody exists, a positive reaction after the addition of antihuman serum indicating incompatibility.

A false negative reaction could have serious consequences since it would constitute an incorrect indication of blood compatibility. While automatic analysis equipment is now used with increasing frequency in laboratories because of the greater speed and reliability of automated procedures in contrast to manual pro-

cedures, there is a continuing danger that malfunctioning of the equipment might give misleading results. For example, in the operation of equipment designed to carry out the Coombs test, false negative reactions would be expected to occur if for some reason the drop of Coombs serum was not added to each test tube in the final stages of the procedure, or if for some reason an insufficient amount of serum were so added. The problem is further complicated by the fact that upon exposure to air, Coombs serum becomes increasingly viscous and may clog the passage of the drop-dispensing mechanism. While the problem is particularly well illustrated by the Coombs test, and by equipment designed to perform that test automatically, the same problem exists in varying degrees in the automation of other laboratory tests requiring dropwise addition of reagents.

The specific problems described above have not been fully solved in the past despite considerable effort in that regard. Photoelectric devices have previously been known and used for detecting the presence or absence of fluids but such devices, along with other safety measures, have not resulted in automated drop-dispensing laboratory equipment which is sufficiently reliable, non-clogging and substantially maintenance-free. United States Patent Specification Nos. 3,225,191, 3,454,759, 2,446,885, 3,038,300, 3,418,053, 2,718,597 and 3,548,193 are illustrative of the prior art.

This invention is concerned with a drop-dispensing apparatus for laboratory reagents which is relatively simple in construction and operation. The apparatus includes a tube for dispensing drops of liquid such as, for example, antihuman Coombs serum, which is constructed and arranged so that it is non-clogging in operation. A photoelectric detector system may be used to

detect a drop after it has been released from the tube and is traveling downwardly into the reaction tube, such system cooperating with the drop dispensing portion of the apparatus to trigger the reaction of liquid in the tube immediately after a drop has been released. Because of the substantial extent of liquid reaction in the tube following the dispensing of each drop, the bore of the tube remains clear and unobstructed to ensure proper operation when the dispensing of a further drop is later required. Such retraction occurs because of the configuration and dimensions of the tube and because of the structural relationship between the tube and the container and its contents; thus, retraction occurs automatically when the container is vented. Since the venting of the container is caused by de-energization of an electro-magnetic valve which is in turn actuated by interruption of a light beam by a falling drop of liquid, liquid in the tube is in its fully retracted condition when the drop dispensing apparatus is in a state of rest.

The photo-electric detector is oriented with respect to the tube so that its beam is interrupted only by a drop which is falling from the tube, and not by one which is being formed at the tube tip. Such a relationship helps to ensure that a false signal will not be produced by the drop detector and, in particular, that retraction of liquid in the tube, and other operations of the apparatus which immediately follow drop discharge, will not occur unless a drop has actually been released from the tube and has traveled downwardly along its line of free fall. Reliability and accuracy are further ensured by the use of a beam-confining apertured plate and by the fact that the selected photocell, a photo-transistor in this case, is sensitive only to light in the infrared portion of the spectrum, to reduce the effects of stray ambient light. However, other wavelengths may be used, although such additional advantages will necessarily be sacrificed.

The tube is formed of a relatively rigid and dimensionally stable material, preferably glass. Specifically, the tube includes an elongate stem portion which is adapted to extend downwardly into a reagent bottle through the mouth thereof, an intermediate portion which projects transversely from the stem portion's upper end, and a tip extending from the distal end of the intermediate portion parallel to the stem. The tip terminates in a flat annular end surface which has an outside diameter no greater than 4.0 millimeters. A bore extends throughout the length of the tube and has a diameter in the range of 0.25 to 3.0 millimeters. The tip portion of the tube has a length which constitutes only a minor proportion of the

vertical length of the stem portion.

An embodiment of the invention will be described by way of example, reference being made to the drawings of which:—

Figure 1 is a vertical section of a drop dispensing apparatus with certain components, such as a photo-electric detector system.

Figure 2 is an elevation of the tube and reagent bottle;

Figure 3 is an enlarged fragmentary vertical section of the tip portion of the tube; and

Figure 4 is an enlarged section similar to Figure 3 but illustrating the tip during drop formation.

The drop dispensing apparatus illustrated in Figure 1 comprises a tube 10, a reagent container 11, photo-electric drop detector 12, and gas supply and control 13. For most applications such gas would be air; however, where necessary or desirable, any other gas or combination of gases might be used.

Tube 10 is formed of a relatively rigid, dimensionally - stable, and non - reactive material such as glass. As shown in Figures 1 and 2, the tube is of inverted J-shaped configuration, having an elongate upstanding stem 14, a horizontally-extending intermediate portion 15, and a depending tip 16. The tube is integrally formed with a bore 17 extending throughout the full length of it. The depending tip 16 terminates in a flat horizontal end surface 18. For proper drop formation the annular end surface 18 must have a uniform outside diameter no greater than 4.0 millimeters and an inside diameter in the range of 0.25 to 3.0 millimeters. For use in a Coombs serum delivery system, the optimum inside diameter is believed to be about 0.5 millimeters.

The container or bottle 11 has an open upper end defined by threaded neck 19. Closure means, in the form of cap 20 and resilient stopper 21 seal the mouth of the bottle. As shown most clearly in Figure 1, the upstanding or vertical stem 14 extends downwardly through an opening 22 in the stopper, the bottom end of the stem terminating a slight distance above the bottom inside surface of the bottle. The liquid contents of the bottle are designed generally by the numeral 23 with the maximum level of such liquid being represented by line x in Figure 2. Because of capillary action, the level of the liquid within the bore of tube 10 stabilizes at a point well above the level of the liquid in the bottle. The maximum elevation of liquid in stem 14 by reason of such capillary action is indicated by line y in Figures 1 and 2. That level of liquid within the stem is achieved when the interior of the bottle is at atmospheric pressure and the level of the bottle's fluid contents is at

a maximum (i.e., when the bottle is filled to the level represented by line x).

Even when liquid within stem 14 has risen to the maximum level y by reason of capillary action, that level is still substantially below the horizontal plane z of the tube bottom end surface 18. Also the difference in elevation between z and y will increase as the contents of the bottle are depleted. Thus, Figures 1 and 2 illustrate conditions under which the distance between y and z is at a minimum.

Liquid is discharged from the tube by altering the equilibrium conditions, that is, by increasing pressure within the bottle to displace liquid from the bottle through the tube and into a reaction tube or other receptacle 24. In the illustration given, the pressure increase is achieved by means of the gas supply and control 13 which includes an air pump 25, conduit 26, needle valve 27, electro-magnetic valve 28, and filter 29. As shown in Figure 1, conduit 26 is connected to a tubular coupling 30 which is received in passage 31 in stopper 21. Upon operation of the air pump 25, which may be a simple electric diaphragm pump, a stream of air under pressure passes through conduit 26 into the upper end of bottle 11 assuming, of course, that valve 28 is open.

The electro-magnetic control valve 28 is of the type which blocks the flow of air under pressure from pump 25 only when the valve is deenergized. When in a deenergized condition, the electro-magnetic valve vents to atmosphere that portion of conduit 26 extending between valve 28 and bottle 11. Since the construction and operation of such a valve is well known, and since valves of that type are commercially available, a detailed description of the structure and operation of valve 28 is believed unnecessary herein.

The operation of electro-magnetic valve 28 is controlled by the photo-electric drop detector 12. The latter includes an infrared light source 32, an apertured plate 33 for confining the beam from the source, and an infrared light detector 34. The source or emitter 32 and receiver or detector 34 are part of a circuit 35 which is electrically connected to electro-magnetic valve 28 so that the valve will remain energized, and will therefore admit the flow of pressurized air to bottle 11, as long as the beam of light from source 32 to receiver 34 remains unbroken. Source 32 and receiver 34 are spaced well below the tip 16 of tube 10 with the beam therebetween extending across the path of a drop 36 as it falls directly from the tip towards receptacle 24. Interruption of the infra red beam by the falling drop is detected by receiver 34 and circuit 35 and the latter immediately deenergizes electro-magnetic valve 28, which then remains de-

energized until reset by circuit 35 in conjunction with any suitable resetting mechanism (not shown). For example, resetting may be delayed until reaction tube 24 has been withdrawn and another reaction tube has been put into position by a suitable transport mechanism (not shown).

While photoelectric detectors are well known, and while elements 32 to 35 are standard components, the relationship of such elements to the other elements of the apparatus is believed to be unique. Valve 28 is not deenergized until a drop has not only been formed at the end of the tube but has actually been released from the tube and is falling towards the receiving tube 24. The instant the beam is interrupted, air in bottle 11 is vented to the atmosphere and, because of the equalized pressure and the differential head, liquid immediately retracts from the tip and intermediate portions of the tube into stem 14. Because of the retraction of liquid well away from the end surface of tip 16, the dangers that the liquid might become contaminated through exposure at the tip, or might dry or harden and thereby clog the tip, are greatly reduced if not completely eliminated. The result is a relatively simple but highly effective drop dispensing apparatus particularly suitable for use in automated laboratory equipment.

WHAT WE CLAIM IS:—

1. Apparatus for the dropwise dispensing of a liquid from a bottle, comprising a tube formed integrally of a relatively rigid and dimensionally-stable material and having a bore extending throughout its length; the tube having an elongate stem adapted to extend downwardly into a reagent bottle through the mouth thereof, an intermediate portion projecting transversely from the stem's upper end, and a tip extending from the distal end of the intermediate portion parallel to the stem, the tip terminating in a flat annular end surface and having an outside diameter no greater than 4.0 millimeters; the bore being of a diameter within the range of 0.25 to 3.0 millimeters; and the tip having a length constituting a minor portion of the length of the stem.

2. The apparatus of Claim 1 in which the bore is of substantially uniform diameter throughout its entire extent.

3. The apparatus of Claim 2 in which the diameter of the bore is approximately 0.5 millimeters.

4. The apparatus of Claim 1 in which the material is glass.

5. An apparatus for the dropwise dispensing of liquids, comprising a bottle containing a liquid; the bottle having a mouth at the upper end thereof and having closure means closing the mouth; an inverted generally J-shaped tube formed integrally of a relatively rigid and dimensionally-stable

- material and having a bore extending throughout its length; the tube having an elongate stem extending downwardly into the bottle through the closure means, an intermediate portion projecting laterally from the stem's upper end, and a depending tip at the distal end of the intermediate portion; the bore in the tip being of a diameter lying in the range of 0.25 to 3.0 millimeters; and the tip having a length constituting a minor portion of the length of the stem with the end of the tip terminating a substantial distance above the maximum height to which liquid in the bottle is capable of rising in the stem by reason of capillary action, the closure means being provided with a passage for the introduction of gas under pressure into the bottle and the resulting displacement of liquid from the bottle through said tube.
6. The apparatus of Claim 5 in which the tip terminates in an annular end surface lying in a horizontal plane and having an outside diameter no greater than 4.0 millimeters.
7. The apparatus of Claim 5 in which the diameter of the bore in the tip is approximately 0.5 millimeters.
8. The apparatus of Claim 5 in which the bore is of substantially uniform diameter throughout its entire extent.
9. The apparatus of Claim 5 in which the tube is formed of glass.
10. An apparatus for the dropwise dispensing of liquids, comprising a bottle containing a liquid; the bottle having a mouth at the upper end thereof and having closure means closing the mouth; an inverted generally J-shaped tube having an elongate stem extending downwardly into the bottle through the closure means, an intermediate portion projecting laterally from the stem's upper end, and a depending tip at the distal end of the intermediate portion; the tip terminating in an annular end surface lying in a generally horizontal plane; the tube having a bore extending therethrough of a diameter in the range of 0.25 to 3.0 millimeters; the tip having a length constituting a minor portion of the length of the stem with the annular end surface disposed a substantial distance above the maximum height to which liquid in the bottle is capable of rising into the stem by reason of capillary action; the closure means being provided with a passage for the introduction of gas under pressure into the bottle for the displacement of liquid from the bottle through the tube; means communicating with the passage for discharging gas under pressure into the passage; and valve means interposed along the passage for interrupting the flow of gas under pressure into the bottle and for simultaneously venting the passage and bottle to atmospheric pressure, whereby, upon the interruption of the gas flow and the venting of the passage and bottle to atmospheric pressure, liquid in the tube retracts from the tip and intermediate portion into the stem.
11. The apparatus of Claim 10 in which detector means are disposed below the tip for detecting the release of a drop of liquid from the tip and for actuating the valve means to interrupt the gas flow and cause retraction of the liquid in the tube when the detection occurs.
12. The apparatus of Claim 11 in which the detector means includes a light source and a light receiver disposed on opposite sides of the path of travel of a drop falling from the tip of the tube.
13. The apparatus of Claim 12 in which the source emits infra red light and the receiver is responsive only to infra red light.
14. The apparatus of Claim 12 in which an apertured plate is interposed between the path of travel of the drop and light receiver, the plate being opaque and having an aperture aligned with the source and the receiver whereby, the plate serves as a mask for confining the light along a substantially direct line between the source and the receiver.
15. Apparatus for the dropwise dispensing of liquids substantially as hereinbefore described with reference to the accompanying drawings.

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